Mitchell J. Kellermeyer

Honors Thesis:

An Economic Comparison of Super-Energy-Efficient Houses to Standard Built Houses

Qian Chen, Ph.D. – Advisor
Construction Systems Management Assistant Professor
Dept. of Food, Agricultural and Biological Engineering
The Ohio State University

Table of Contents

Chapter 1- Introduction

1.1 – Background

The U.S. Green Building Council stated buildings are responsible for 36 percent of total energy use and 65% of electricity consumption, 30 percent of greenhouse gas emissions, 30 percent of raw material use, 30 percent of waste output and 12 percent of potable water use (ULI- the Urban Land Institute 2008). According to U.S. Environmental Protection Agency, residential buildings (homes) alone account for 22% of national energy use and 21% of carbon dioxide emissions. With the high amount of energy used by buildings including homes, there will be a greater need for coal. By 2030 an estimated 80 percent more coal will be needed, shifting the U.S. to have to import more coal from other countries (Heinberg). Emissions from buildings are also considered a contributing factor that is changing our climate. (*Problems: Global Change and Global Warming).*

For the past few decades, various energy efficient building technologies have been developed. However, energy efficient homes are still limited nationwide. In 2006, only 200,000 out of 1,801,000 new houses built earned the Energy Star for their energy efficiency (EPA 2007). To be qualified for Energy Star the house must be 15 percent more energy efficient than homes built to the 2004 International Residential Code (EPA 2007). Based on an article titled, “Energy Consumption,” energy efficiency can be increased for buildings by reducing air infiltration with weather-stripping and caulking, providing good insulation in walls and attic spaces, controlling temperature in the house with programmable thermostats, and properly maintaining heating and cooling systems (Secondary Energy Infobook).

An example of an energy efficient home would be Allen Zimmerman’s home. The home had an average total annual electric energy consumption of 5.5 kWh per square foot. Similar homes in central and northern Ohio that are powered solely by electricity have an annual consumption of 9.3 to 11.7 kWh per square foot. Energy efficient building methods implemented in this case included using 2 by 6 stud walls spaced 24 inches on center, placing the specific rooms facing directions to avoid excessive solar gain, determining appropriate window sizes and locations, installing raised-heel trusses to allow more insulation in the attic and a larger overhang to provide maximum shading in the summer, installing an automatic ventilation system, and using energy-efficient fluorescent lamps (Zimmerman 2007).

Super-energy-efficient (SEE) homes are based on system design and precision construction to improve the efficiency of homes by around 50 percent. With 56 percent of annual energy bills coming from heating and cooling, finding ways to improve the energy efficiency of the home by reducing the heating and cooling loads is important (Global Green USA 2007). This could be achieved through 2 by 6 walls spaced 24 inches on center to allow better wall insulation, extra interior and exterior finishes, modified framing for added insulation in the attic, and better air barriers around doors and windows.

SEE Homes are known in the residential construction industry, but they are not practiced often. Potential increase in construction costs is prohibitive to both homebuilders and buyers. Some people assume that the home will be weaker if the studs are spaced out 24 inches on center instead of 16 inches on center. This is a myth and has not been proved to cause weaknesses in the house. Some also think that making the house too air tight will cause stuffiness to the occupants. But if a proper ventilation system is installed the house can be made more air tight without causing any indoor air quality problems. Another reason SEE homes are less common is because of the lack of knowledge and experience on the contractor's side to build them. The wide acceptance and implementation of SEE home building technologies could take a little extra time and the positive changes would significantly reduce energy consumption in the U.S.

This research aims to tackle several major impediments that prevent SEE homes from being widely built in America.

1.2 - Problems

1. Lack of System Approach

While energy efficient building technologies have been developed for many years, their use in the field is usually not based on a systems approach. A systems approach aims to study the whole building including all the subsystems to improve the energy efficiency. For a building to be energy efficient, one or two changes will not significantly impact the energy saved. For example, using high performance windows with a poorly insulated home may not be able to reduce energy consumption of a home.

2. Increased Construction Costs

Most builders believe that energy efficient homes cost much more to build. This actually increases their selling price for this type of homes, making them less competitive in the residential market. However, if a prepared design and construction approach is developed, an energy efficient home may not necessarily cost more to build.

3. Payback Problems

Homeowners feel that they have to pay more for energy efficient homes, but there is no clear evidence for them if the increased costs can be recovered during their stay in the home. Therefore, it will be greatly helpful to show them that the increased costs could be offset by savings on their utility bills within a reasonable time period. For example, if a home in Ohio is Energy Star rated, it will cost around two or three hundred less dollars each winter to pay for heating (Duke Energy).

1.3 - Hypothesis/ Objectives

1. Fifty Percent Increase in Energy Efficiency

A well designed and constructed super-energy-efficient home could be fifty percent more energy efficient compared to homes built to current code and save the home owner significant amount of money over time. This research aims to improve the energy efficiency of current housing designs by considering energy efficiency improvements on building envelope and related building subsystems.

2. Minimal or No Additional Construction Costs

A well designed and constructed super-energy-efficient home may not cost the builders more to build and therefore would not cost more for homeowners. This research will compare construction costs between a normal home constructed to the standard code and a home constructed with improvements to the whole home for more energy efficiency. The expected results will prove that the cost increase of energy efficient homes will be minimal when compared to the standard homes.

3. Short Payback Period

If the SEE home costs slightly more, it is expected that the cost difference can be paid off in energy savings. Once we know the difference in the cost and the amount of money the super-energy-efficient home saves in heating and cooling, we can determine how many years are needed for the added cost to be paid back. The expected results will prove that the super-energy-efficient home could be paid off in less than five or ten years.

1.4 – Procedures

The first step is to research and initiate energy efficiency improvements and to have a meeting with advisors to determine what improvements should be made to the standard homes. Some improvements could be replacing 2x4 studs with2x6, upgrading the interior and exterior finishes, altering the framing and trusses style for more insulation in the attic, and adding better air barriers around doors and windows.

The second step is to take the energy efficiency improvements that are considered and compare them in an energy simulation program called “eQUEST.” A variety of combinations for the whole home could be studied on the software to build the most energy efficient home.

The third step is to estimate both the initial cost and the updated cost (with energy efficiency improvements) for three selected home plans in 2,000, 3,000, and 4,000 sq. ft., respectively. That means after estimating the cost to construct the standard home at each size, the cost of the same size energy efficient home will also be estimated. These estimates will give the home builders and owners more knowledge of the actual construction cost increase for energy efficiency improvements.

Once all the estimating is performed and the differences in costs are identified, the findings can be recorded for the thesis and presentation. If the super-energy-efficient house style costs more, the time needed to pay that cost off will be determined. The increased cost and resulting energy savings will be known so determining the payback period will be straightforward.

1.5 - Organization of Thesis

The first chapter of the thesis focuses on the background of energy efficient homes and the importance of including energy improvement techniques. After that the research problems, objectives and procedures are discussed.

The second chapter reviews different techniques to improve the energy efficiency of houses. A case, a super-energy-efficient home built in Ohio, is presented. The energy simulation software selected for this research is also briefly reviewed.

The third chapter presents the results we found from the research. The first part of the chapter is all about the energy improvement techniques we choose to change between the baseline house and the energy efficient house. The second part discusses the difference in prices between the baseline houses and the energy efficient houses that we estimated. The third part of the chapter addresses the change in energy consumption based simulation results from eQUEST. The fourth part brings together our findings about the extra costs and potential energy savings. Based on the information, the payback period is calculated.

Chapter 2 – Literature Review

2.1 – Energy Efficient Housing

2.1.1 – Introduction

It can be confusing what structures of a standard house need improved to make it an energy efficient house. Bruno Zager stated, "Any house can be made more energy efficient. You don't need a designer; you just need to know a little about how a house works as a system," (Sikora 2002). Some major changes from Jeannie Leggett Sikora's book, *Profit from Building Green*, can be advanced framing, structural insulated panels, insulated concrete forms, double 2-by-4 walls, prefabricated walls, raised-heel roof trusses, different styles of insulation, radiant barrier roof sheathing, frost-protected shallow foundations, and selection of windows to improve the house (Sikora 2002).

2.1.2 – Advanced Framing

Advanced framing would include increased stud spacing, the use of California or two-stud corners, or other methods to improve insulation in the house's corners. From these techniques, the homeowner can save up to $1000 in material costs on a 2400 square-foot house. They could save three to five percent on labor costs and two to three percent in annual heating and cooling costs. Not included in advanced framing techniques, but could save the homeowner even more money is using 2-inch by 6-inch studs to increase the amount of insulation that can be inserted into the wall cavity. The more the insulation, the higher the R-value the wall has to resist heat loss. Once construction workers are familiar with techniques of advanced framing, there will not be an increase in cost or a longer installation time (Sikora 2002).

2.1.3 – Structural Insulated Panels

Another technique to increase the homes energy efficiency is from upgrading the envelope of the home with structural insulated panels. A structural insulated panel is a rigid foam interior surrounded by to layer of oriented strand board (OSB). Unlike advanced framing this technique would increase the wall cost by about two percent and it would take a normal construction crew an extended time to install. Another problem is a crane and other special equipment would be needed to set them into place (Sikora 2002).

2.1.4 – Insulating Concrete Forms

If the wall of the house is made of concrete or the homeowner wants to insulate the foundation walls, the homeowner could use insulating concrete forms. Rigid plastic foam forms are placed to form up the concrete walls and can be left in place after the concrete hardens to provide extra insulation. These insulating forms would provide thermal insulation for the concrete walls. Usually the walls are formed by wood and metal forms that are removed from the wall (Sikora 2002).

2.1.5 – Double 2-inch by 4-inch Walls

Similar to advanced framing, that could improve the house, is using double 2-inch by 4-inch walls. Two walls are placed together with a four inch space allowing a twelve inch cavity. The cavity allows for an R-value of 38 from the insulation. The problems from this technique is losing some interior square footage of the home and the wall costs would be about twice as expensive (Sikora 2002).

2.1.6 – Prefabricated Walls

Prefabricated walls are walls that are constructed ahead of time in a factory where there is a worker friendly environment. The workers do not have to worry about weather problems or other problems faced on an actual construction site. Fabrication in a factory allows recycling and easier reuse of materials. This procedure allows for quick installation and minimizes construction defects. Along with the advantages comes a three to five percent material cost increase (Sikora 2002).

2.1.7 – Raised-Heel Roof Trusses

Raised-heel roof trusses are important because normal roof trusses allow for only a small space for insulation above the cap plate of the wall. If the insulation is squeezed into the small space, the insulation's R-value is reduced. Switching to raised-heel roof trusses provides extra inches for insulation above the cap plate. Using a larger overhang also increased the amount of space above the cap plate. As the overhang increases, the narrow part of the truss continues to extend further past the wall (Sikora 2002).

2.1.8 – Insulation

Different insulations that can be used are batt insulation, cellulose insulation, spray foam insulation, insulating sheathing, and radiant barrier roof sheathing. Batt insulation is cost effective to use in energy efficient homes and good for 2-inch by 6-inch stud walls and double walls. Cellulose insulation has a higher R-value per inch thickness of insulation. The R-value is from R-3.55 to R-3.85 per inch. It is made from recycled newspaper and the news print waste from printing presses, and it can be used in loose fill or wall-spray form. Spray foam insulation has an R-value of 3.6 per inch and creates a barrier against air infiltration. With this barrier, additional products to ensure tightness are not needed, but spray foam insulation is about four times more expensive than normal batt insulation (Sikora 2002).

Another way to add more insulation to a home is through sheathing. It is placed on the exterior of the house and can cover areas of the house with no insulation. Part of the wall consists of the studs which provide poor insulating capabilities. The sheathing can be placed on the entire exterior to insulate those areas better. Radiant barrier roof sheathing is a thin piece of aluminum foil placed on the OSB for the roof. The extra aluminum foil can be about ten to fifteen more expensive than a regular piece of OSB. The aluminum foil blocks radiant heat transfer into the attic, consequently helping keep the attic temperature down (Sikora 2002).

2.1.9 – Frost-Protected Shallow Foundations

Another technique to increase the energy efficiency of a home is by adding rigid foam insulation board around the outside of the foundation wall. This helps raise the frost level and allowing for a shallower foundation. This would then result in savings from excavating and material costs. The savings are about fifteen to twenty-one percent more compared to standard foundations (Sikora 2002).

2.1.10 – Window Selection

While selecting a window, the homeowner could compare the National Fenestration Rating Council (NFRC) rating. The rating compares the U-factor or the rate of heat conduction through the window, the solar heat gain coefficient and the visible transmittance. When the U-factor increases the window's resistance to heat flow increases. To find a higher U-factor, the homeowner can find a window that has low-E coating on the glass, an inert gas in the airspace between the two panes of glass, and a better insulated frame and sash. The solar heat gain coefficient is the ratio of solar energy transmitted through the window over the total solar radiation. The visible transmittance of the window is the amount of visible sunlight that passes through the window as light. Another factor that can be compared between windows is the air infiltration rate. The air infiltration rate is the amount of air that enters into the house through cracks and gaps (Sikora 2002).

2.2 - Related Research

2.2.1 – Allen Zimmerman

One of my advisors, Allen Zimmerman, built his home a few years ago with energy efficiency improvements that I want to address. He placed 2 by 6 inch studs that were spaced 24 inches on center, while typical homes have walls with 2 by 4 inch studs spaced 16 inches on center. The extra space allows for more insulation which leads to less heat loss. More heat is lost where the studs are than where insulation is. The bigger studs allow them to be spaced out more and less surface areas of studs to allow heat out of the building. He also adjusted his room framing to add more insulation in the attic and to add a hangover to block sun into the windows. To insure tightness he applied air-tight dry wall in the interior and taped extruded polystyrene sheathing for the exterior of the walls. He installed a ventilation system that is connected to a humidistat and the system can be automatically opened if the humidistat detects too much humidity in the home. With the ventilation system, he can also control how many times it opens each day to allow fresh air in (Zimmerman, 2007).

The temperature in Allen Zimmerman's home is set to about 65 degrees Fahrenheit and his house has an average total annual electric energy consumption of 5.5 kWh per square foot. Similar homes in central and northern Ohio that are powered solely by electricity have an annual consumption between 9.3 kWh per square foot and 11.7 kWh per square foot. Allen Zimmerman's home is similar to another experiment that showed these techniques can definitely save the home owner money just through electricity consumption (Zimmerman, 2007).

2.3 – eQUEST

The energy simulation tool we used in our research project is called eQUEST. The program combines a building creation wizard, an energy efficiency measure (EEM) wizard and a display module that provides tabular and graphical results. The program walks you through a building creation wizard where the user can create their own building through specific details. The wizard helps the user describe the architectural design, HVAC equipment, building type and size, floor plan layout, construction materials, area usage and occupancy, and lighting system (Energy Design Resources).

Chapter 3– Results

3.1 – Energy Improvements Applied

In chapter 2, I discussed some improvements that could be applied to a house, but not all of them could be applied to the same house. In our research of approaching the house as a full system, we wanted to find improvements that could work together to get the best energy efficiency. One of the main improvements we implemented into our houses was changing the wall framing from 2-inch by 4-inch studs spaced 16 inches center to center to 2-inch by 6-inch studs spaced 24 inches center to center. EQUEST provided a tool to select all different size studs and spacing. To increase the insulation in eQUEST, we placed R-11 batt insulation in the 2-inch by 4-inch studded wall and R-19 batt insulation in the 2-inch by 6-inch studded wall because of the increased amount of space created from the extra depth.

Another improvement we applied to the house was to add more exterior insulation. On the base house, we placed 1 inch of polystyrene and on the energy efficient home, we placed 2 inches of polystyrene. We also decided to use raised heel trusses for the energy efficient house. With this improvement, we increased the overhang of the roof from 2 feet to 4 feet. This improvement also added more insulation. For eQUEST, we went from R-38 insulation in the attic for the base house to R-49 insulation in the new designed house. These numbers were determined by my advisor, Allen Zimmerman. He has studied the increased amount of insulation that can be placed in a house with raised heel trusses compared to a house with standard trusses.

Along with the extra insulation in the energy efficient house, we also wanted to increase the tightness of the house. To increase the tightness, we added a house wrap that would change from .8 air changes per hour for the standard new house to .35 air changes per hour for the energy efficient house. To also watch the amount of air that infiltrates the house, we wanted to improve the windows. In the baseline house model, we used normal double pane windows and for the energy efficient house we selected double pane windows that were gas filled.

Also to increase energy efficiency, we used a gas furnace with 95 percent annual fuel utilization efficiency (AFUE) in the energy efficient house and 87 AFUE in the baseline house. Similar to the furnace, we also looked at the seasonal energy efficiency ratio (SEER) on the air conditioner. With the baseline house, we used 13 SEER and for the energy efficient house, we used 16 SEER. These two ratings help control the energy efficiency, but will also increase the cost of the electric air conditioning unit and gas furnace unit.

3.2 – Cost Differences

When estimating the cost of the two houses, we focused only on the items in the house that would change. Through the estimating technique, RS Means, we estimated the difference of the two houses (CostWorks, RSMeans). The changes that increase the cost of the SEE house was the same for the 2000, 4000, and 6000 square foot house. The tables to compare the 2000 square foot house are included below and all the tables are included in Appendix A.

2000 Square Foot Baseline House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x4 Walls, 16” spacing	06 11 10.26 0407	LF	$5.98	200	$1,196.00
Insulation, 15" wide, 3.5" thick	07 21 16.20 0080	SF	$1.52	1624.5	$2,469.24
Windows	08 51 13.20 2000	Ea	$428.87	11	$4,717.57
Exterior Insulation, 1" thick	07 24 13.10 0095	SF	$4.80	1800	$8,640.00
Ceiling Insulation, 9" thick, R-36	07 21 23.10 0080	CF	$1.47	1875	$2,756.25
Furnace, 87 AFUE		EA	$1,308.00	1	$1,308.00
Air Conditioner, SEER 13		EA	$948.99	1	$948.99
Total					**$22,036.05**

2000 Square Foot SEE House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x6 Walls, 24” spacing	06 11 10.26 1107	LF	$5.95	200	$1,190.00
Insulation, 23" wide, 6" thick	07 21 16.20 0180	SF	$1.75	1683	$2,945.25
Windows, insulated	08 51 13.20 2050	Ea	$453.60	11	$4,989.60
Exterior Insulation, 2" thick	07 24 13.10 0105	SF	$5.13	1800	$9,234.00
Ceiling Insulation, 12" thick, R-48	07 21 23.10 0080	CF	$1.47	2500	$3,675.00
Vapor barrier	07 25 10.10 0480	SF	$0.17	1800	$306.00
Ridge Board	06 11 10.30 5861	LF	$1.15	400	$460.00
Furnace, 95 AFUE		EA	$2,700.00	1	$2,700.00
Air Conditioner, SEER 16		EA	$1,930.99	1	$1,930.99
Total					**$27,430.84**

As seen in the two tables, the framing of the 2-inch by 6-inch wall was actually cheaper per linear foot than the 2-inch by 4-inch framing. The insulation costs more in the 2-inch by 6-inch wall cavity because of the increased thickness and width. The windows for the SEE house that were insulated cost about $25 more per window. When comparing the prices between the different houses sizes, the windows play a major factor because the bigger the house, the more windows that was installed. In the baseline house a 1” thick exterior insulation was used and a 2” exterior insulation in the SEE house was used. This change increased the cost by $0.33 for every square foot of exterior walls surface.

The ceiling insulation also increased by 3 inches, increasing the volume of insulation from 1875 cubic feet to 2500 cubic feet in the 2000 square foot house. Along with the increase in ceiling insulation, we also included the cost of adding a ridge board around the house to lift the ceiling trusses up. The ridge board added $1.15 per linear foot to the SEE house cost. The SEE house also included a vapor barrier when the baseline house did not. The additional cost was

$0.17 per square foot of exterior wall. The last thing changed between the houses was the baseline house had a furnace with 87 AFUE and an air conditioner with 13 SEER and the SEE house had a furnace with 95 AFUE and an air conditioner with 16 SEER. The furnace cost $1,392 more for the SEE house and the air conditioner cost $982 more.

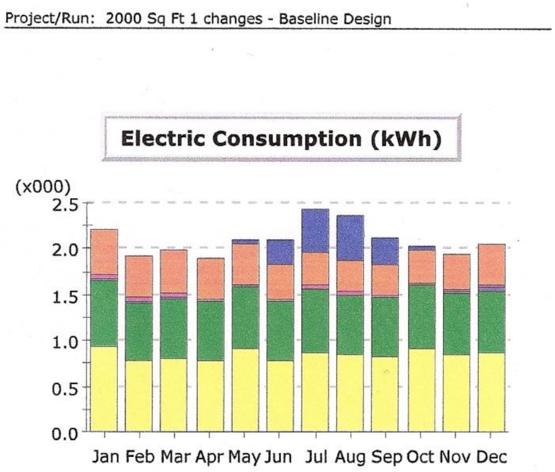
The cost difference between the 2000 square foot houses is $5,394.79. The cost difference between the 4000 square foot houses is $6447.53. The cost difference between the 6000 square foot houses is $8166.46.

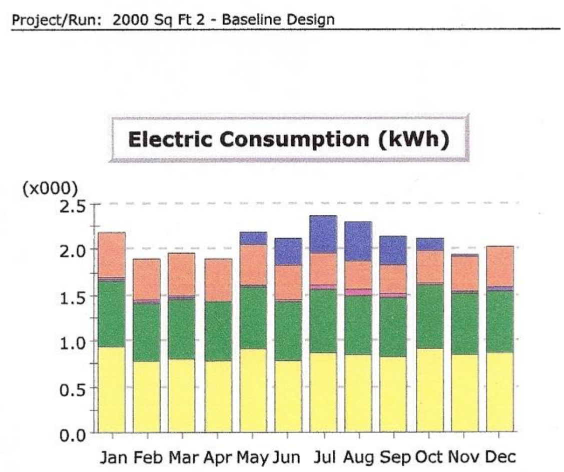
3.3 – Energy Efficiency Differences

After constructing a model for all six houses in eQUEST, we could simulate energy consumption. The simulation results are presented in appendix B. Some parts of the simulation stay the same between the baseline house and the energy efficient house. The parts that are affected by our improvements are space cooling, ventilation fans, and space heating.

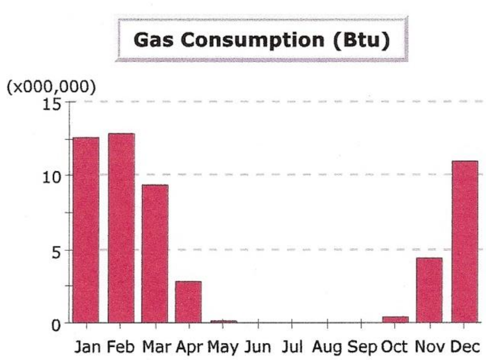
3.3.1 – Annual House Energy Savings

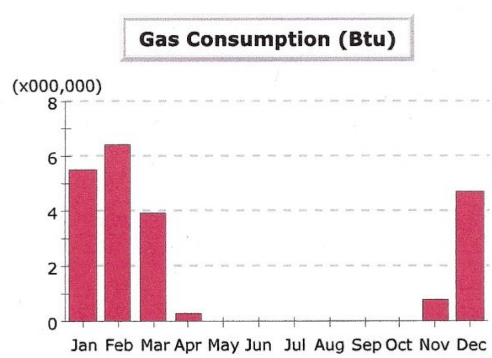
- 2000 Square Foot House:
  - 20 kWh (25,150 kWh – 25,130 kWh)
  - 31,810,000 Btu (53,420,000 Btu – 21,610,000 Btu)





There is a less than 1% savings in electricity consumption



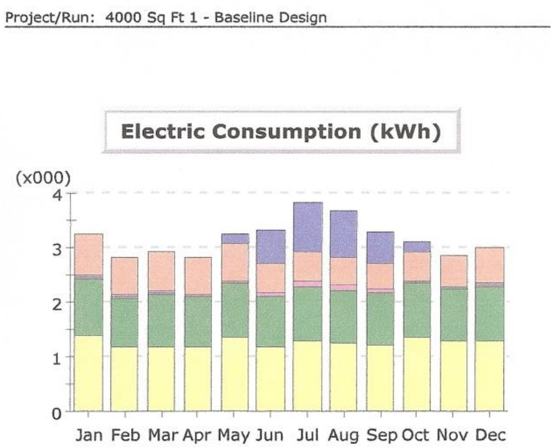


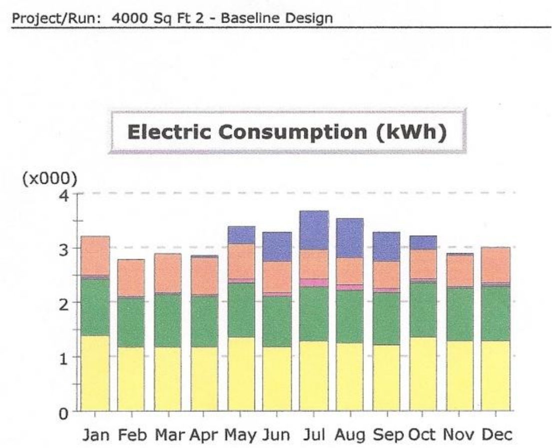
There is a 59.5% savings in gas consumption

- 4000 Square Foot House:

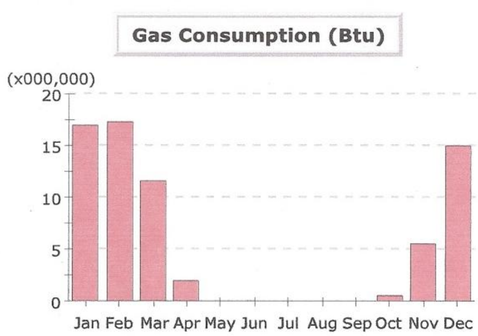
    - <u>110 kWh</u> (38,104 kWh – 38,030 kWh)

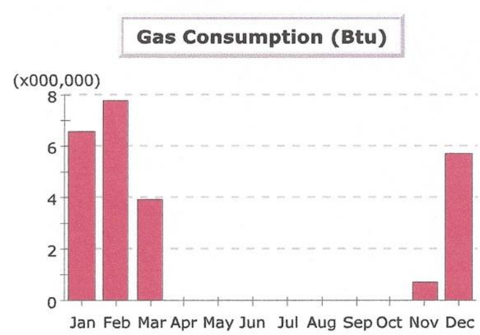
    - <u>44,310,000 Btu</u> (68,960,000 Btu – 24,650,000 Btu)





There is a .3% savings in electric consumption



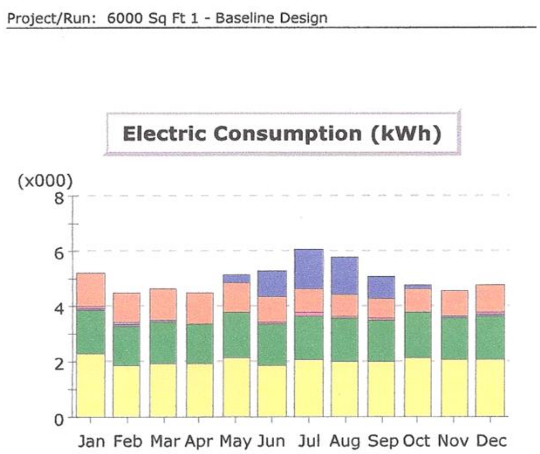


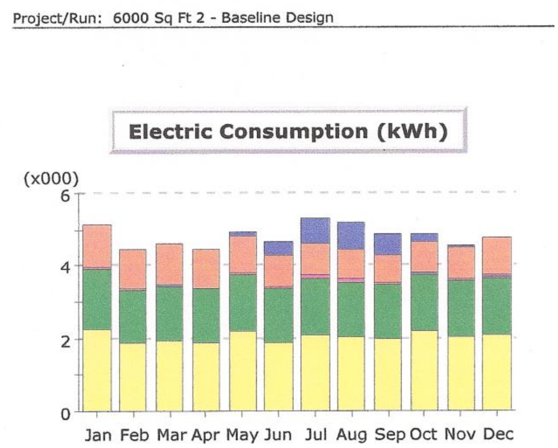
There is a 64.3% savings in gas consumption

- 6000 Square Foot House:

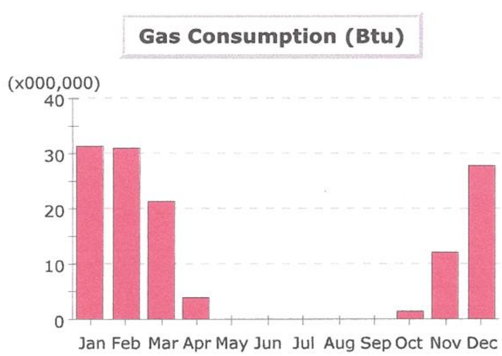
    - 2,580 kWh (60,310 kWh – 57,730 kWh)

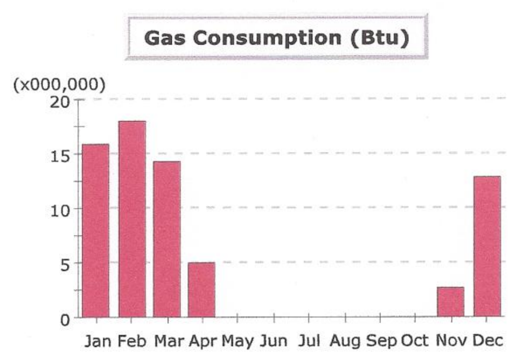
    - 60,510,000 Btu (129,340,000 Btu – 68,830,000 Btu)





There is a 4.3% savings in energy consumption





There is a 46.8% savings in gas consumption

3.4 – Cost Analysis (Payback)

From discovering the electricity and gas consumption reduction and the additional cost accumulated with making these improvements, we can determine a payback period. Previous electric bills from American Electric Power were used to determine a cost of about $.125 per kWh. We also assumed from previous gas bills the cost of natural gas to cost about $13.50 per one million Btu.

3.4.1 – Annual House Utility Bill Savings

- 2000 Square Foot House:
  - $2.50 in electricity (20 kWh)
  - $429.44 in natural gas (31,810,000 Btu)
- 4000 Square Foot House:
  - $13.75 in electricity (110 kWh)
  - $598.19 in natural gas (44,310,000 Btu)
- 6000 Square Foot House:
  - $322.50 in electricity (2,580 kWh)
  - $816.89 in natural gas (60,510,000 Btu)

3.4.2 – Payback in Years (Additional Cost / Annual Utility Bill Savings)

- 2000 Square Foot House:
  - 12.5 years ($5,394.79 / $431.94 = 12.5)
- 4000 Square Foot House:
  - 10.5 years ($6,447.53 / $611.94 = 10.5)
- 6000 Square Foot House:
  - 7.17 years ($8,166.46 / $1139.39 = 7.17)

Chapter 4 – Discussion

The results we found in this research can help to make energy efficiency improvements more common to houses. We presented a rough estimate of how much each improvement will cost to install and an idea of how much money the home owner can save with the improvements. These numbers can be presented to new home owners so they will consider including some improvements in their house as well. With the improvements only taking between seven and twelve years to be paid off, the savings in energy consumption later can be used to pay the house off even faster.

These results can also be used to help expand research on energy efficient home. More research now could be done on studying how much energy each improvement made instead of looking at the improvements as an overall energy efficient system like we did. We approached the research wanting to look at savings with a few improvements that worked together as a system. To really understand which improvement made an impact on its own, research would need to be done on the savings each improvement accounted for by itself.

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Appendix A

A.1 – 2000 Square Foot House Differences

2000 Square Foot Baseline House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x4 Walls, 16” spacing	06 11 10.26 0407	LF	$5.98	200	$1,196.00
Insulation, 15" wide, 3.5" thick	07 21 16.20 0080	SF	$1.52	1624.5	$2,469.24
Windows	08 51 13.20 2000	Ea	$428.87	11	$4,717.57
Exterior Insulation, 1" thick	07 24 13.10 0095	SF	$4.80	1800	$8,640.00
Ceiling Insulation, 9" thick, R-36	07 21 23.10 0080	CF	$1.47	1875	$2,756.25
Furnace, 87 AFUE		EA	$1,308.00	1	$1,308.00
Air Conditioner, SEER 13		EA	$948.99	1	$948.99
Total					**$22,036.05**

2000 Square Foot SEE House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x6 Walls, 24” spacing	06 11 10.26 1107	LF	$5.95	200	$1,190.00
Insulation, 23" wide, 6" thick	07 21 16.20 0180	SF	$1.75	1683	$2,945.25
Windows, insulated	08 51 13.20 2050	Ea	$453.60	11	$4,989.60
Exterior Insulation, 2" thick	07 24 13.10 0105	SF	$5.13	1800	$9,234.00
Ceiling Insulation, 12" thick, R-48	07 21 23.10 0080	CF	$1.47	2500	$3,675.00
Vapor barrier	07 25 10.10 0480	SF	$0.17	1800	$306.00
Ridge Board	06 11 10.30 5861	LF	$1.15	400	$460.00
Furnace, 95 AFUE		EA	$2,700.00	1	$2,700.00
Air Conditioner, SEER 16		EA	$1,930.99	1	$1,930.99
Total					**$27,430.84**

Cost Difference	**$5,394.79**

A.2 – 4000 Square Foot House Differences

4000 Square Foot Baseline House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x4 Walls, 16” spacing	06 11 10.26 0407	LF	$5.98	248	$1,483.04
Insulation, 15" wide, 3.5" thick	07 21 16.20 0080	SF	$1.52	2016	$3,064.32
Windows	08 51 13.20 2000	Ea	$428.87	18	$7,719.66
Exterior Insulation, 1" thick	07 24 13.10 0095	SF	$4.80	2232	$10,713.60
Ceiling Insulation, 9" thick, R-36	07 21 23.10 0080	CF	$1.47	2775	$4,079.25
Furnace, 87 AFUE		EA	1308	1	$1,308.00
Air Conditioner, SEER 13		EA	$948.99	1	$948.99
Total					**$29,316.86**

4000 Square Foot SEE House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x6 Walls, 24” spacing	06 11 10.26 1107	LF	$5.95	248	$1,475.60
Insulation, 23" wide, 6" thick	07 21 16.20 0180	SF	$1.75	2088	$3,654.00
Windows, insulated	08 51 13.20 2050	Ea	$453.60	18	$8,164.80
Exterior Insulation, 2" thick	07 24 13.10 0105	SF	$5.13	2232	$11,450.16
Ceiling Insulation, 12" thick, R-48	07 21 23.10 0080	CF	$1.47	3700	$5,439.00
Vapor barrier	07 25 10.10 0480	SF	$0.17	2232	$379.44
Ridge Board	06 11 10.30 5861	LF	$1.15	496	$570.40
Furnace, 95 AFUE		EA	$2,700.00	1	$2,700.00
Air Conditioner, SEER 16		EA	$1,930.99	1	$1,930.99
Total					**$35,764.39**

Cost Difference	**$6,447.53**

A.3 – 6000 Square Foot House Differences

6000 Square Foot Baseline House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x4 Walls, 16” spacing	06 11 10.26 0407	LF	$5.98	320	$1,913.60
Insulation, 15" wide, 3.5" thick	07 21 16.20 0080	SF	$1.52	2607.75	$3,963.78
Windows	08 51 13.20 2000	Ea	$428.87	27	$11,579.49
Exterior Insulation, 1" thick	07 24 13.10 0095	SF	$4.80	2880	$13,824.00
Ceiling Insulation, 9" thick, R-36	07 21 23.10 0080	CF	$1.47	4500	$6,615.00
Furnace, 87 AFUE		EA	1308	1	$1,308.00
Air Conditioner, SEER 13		EA	$948.99	1	$948.99
Total					**$40,152.86**

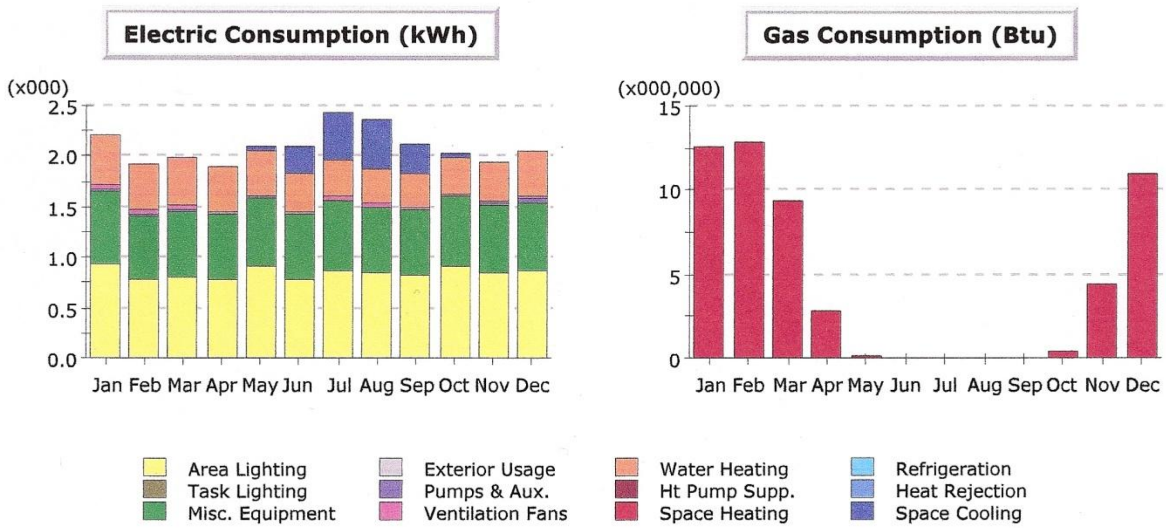
6000 Square Foot SEE House					
Description	**RS Means**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**
2x6 Walls, 24” spacing	06 11 10.26 1107	LF	$5.95	320	$1,904.00
Insulation, 23" wide, 6" thick	07 21 16.20 0180	SF	$1.75	2695.5	$4,717.13
Windows, insulated	08 51 13.20 2050	Ea	$453.60	27	$12,247.20
Exterior Insulation, 2" thick	07 24 13.10 0105	SF	$5.13	2880	$14,774.40
Ceiling Insulation, 12" thick, R-48	07 21 23.10 0080	CF	$1.47	6000	$8,820.00
Vapor barrier	07 25 10.10 0480	SF	$0.17	2880	$489.60
Ridge Board	06 11 10.30 5861	LF	$1.15	640	$736.00
Furnace, 95 AFUE		EA	$2,700.00	1	$2,700.00
Air Conditioner, SEER 16		EA	$1,930.99	1	$1,930.99
Total					**$48,319.32**

Cost Difference	**$8,166.46**

Appendix B - Energy Efficiency Difference Table and Charts

B.1 – 2000 Square Foot Baseline House

Project/Run: 2000 Sq Ft 1 changes - Baseline Design Run Date/Time: 08/17/10 @ 19:18



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	0.05	0.28	0.47	0.48	0.30	0.05	-	-	1.63
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.50	0.45	0.48	0.46	0.45	0.37	0.36	0.33	0.32	0.36	0.38	0.44	4.90
Vent. Fans	0.03	0.04	0.02	0.01	0.00	0.03	0.05	0.05	0.03	0.01	0.01	0.03	0.31
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.70	0.61	0.65	0.63	0.69	0.63	0.68	0.66	0.65	0.69	0.66	0.68	7.92
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.94	0.79	0.80	0.79	0.91	0.79	0.88	0.84	0.82	0.91	0.86	0.87	10.19
Total	2.21	1.92	1.99	1.90	2.10	2.10	2.44	2.36	2.12	2.03	1.94	2.05	25.15

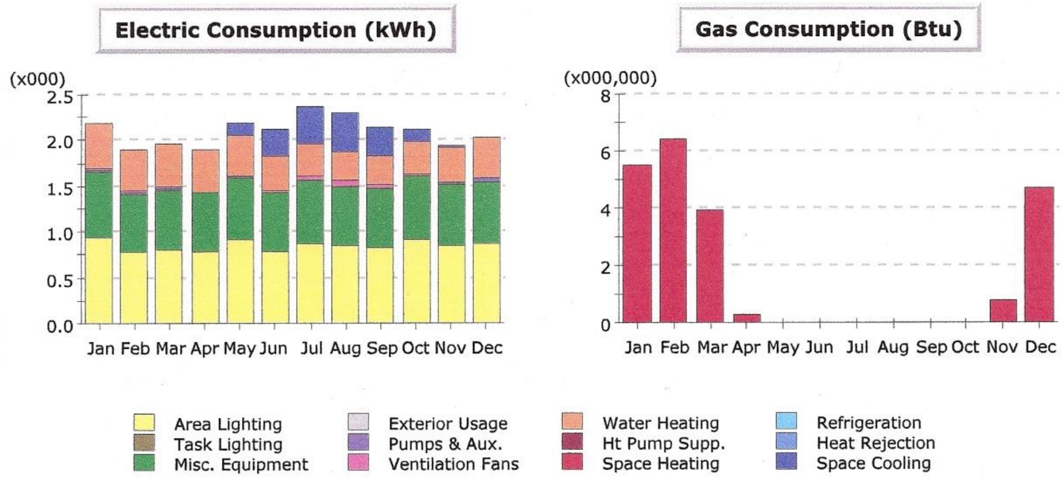
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	12.61	12.79	9.39	2.80	0.07	-	-	-	-	0.42	4.43	10.92	53.42
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.61	12.79	9.39	2.80	0.07	-	-	-	-	0.42	4.43	10.92	53.42

eQUEST 3.63.6510 Monthly Energy Consumption by Enduse Page 1

B.2 – 2000 Square Foot SEE House

Project/Run: 2000 Sq Ft 2 - Baseline Design | Run Date/Time: 08/17/10 @ 19:40



Electric Consumption (kWh x000)

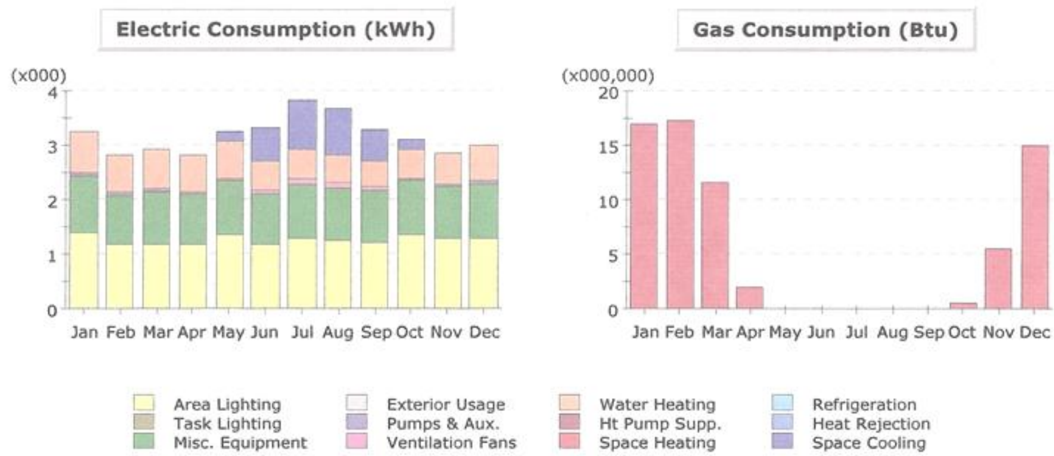
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	0.00	0.12	0.28	0.41	0.41	0.30	0.12	0.01	-	1.64
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.49	0.45	0.48	0.46	0.45	0.37	0.36	0.33	0.32	0.36	0.38	0.43	4.89
Vent. Fans	0.01	0.02	0.01	0.00	0.02	0.04	0.06	0.06	0.04	0.02	0.00	0.01	0.29
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.70	0.61	0.65	0.63	0.69	0.63	0.68	0.66	0.65	0.69	0.66	0.68	7.92
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.94	0.79	0.80	0.79	0.91	0.79	0.88	0.84	0.82	0.91	0.86	0.87	10.19
Total	2.19	1.90	1.97	1.90	2.18	2.11	2.38	2.29	2.13	2.11	1.94	2.03	25.13

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.50	6.40	3.93	0.27	-	-	-	-	-	-	0.76	4.75	21.61
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	5.50	6.40	3.93	0.27	-	-	-	-	-	-	0.76	4.75	21.61

eQUEST 3.63.6510 | Monthly Energy Consumption by Enduse | Page 1

B.3 – 4000 Square Foot Baseline House



Electric Consumption (kWh x000)

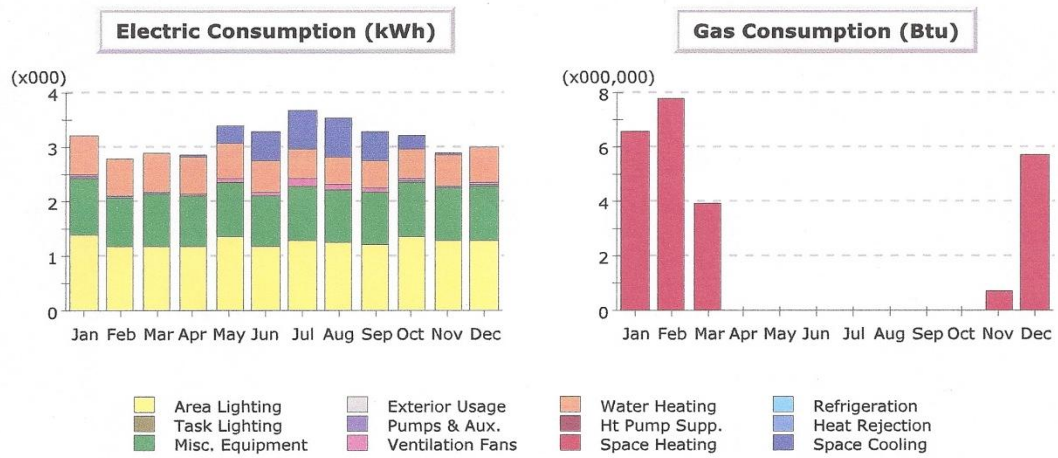
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	0.00	0.20	0.59	0.87	0.87	0.58	0.16	0.01	0.00	3.29
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.73	0.67	0.71	0.68	0.67	0.55	0.54	0.48	0.47	0.54	0.57	0.65	7.26
Vent. Fans	0.05	0.05	0.03	0.00	0.02	0.07	0.10	0.10	0.07	0.02	0.01	0.04	0.56
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.04	0.91	0.96	0.94	1.02	0.94	1.00	0.98	0.96	1.02	0.98	1.00	11.76
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	1.39	1.17	1.19	1.17	1.34	1.17	1.30	1.24	1.22	1.34	1.27	1.29	15.08
Total	3.25	2.82	2.93	2.81	3.26	3.31	3.81	3.68	3.30	3.10	2.87	3.01	38.14

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	16.91	17.25	11.67	1.96	-	-	-	-	-	0.49	5.61	15.07	68.96
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	16.91	17.25	11.67	1.96	-	-	-	-	-	0.49	5.61	15.07	68.96

B.4 – 4000 Square Foot SEE House

Project/Run: 4000 Sq Ft 2 - Baseline Design | Run Date/Time: 08/17/10 @ 20:26



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.00	-	0.00	0.05	0.32	0.54	0.72	0.71	0.53	0.26	0.04	0.00	3.18
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.73	0.67	0.71	0.68	0.67	0.55	0.54	0.48	0.47	0.54	0.56	0.64	7.24
Vent. Fans	0.02	0.02	0.01	0.01	0.05	0.09	0.12	0.12	0.09	0.05	0.01	0.01	0.58
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.04	0.91	0.96	0.94	1.02	0.94	1.00	0.98	0.96	1.02	0.98	1.00	11.76
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	1.39	1.17	1.19	1.17	1.34	1.17	1.30	1.24	1.22	1.34	1.27	1.29	15.08
Total	3.22	2.79	2.90	2.86	3.40	3.28	3.67	3.53	3.27	3.23	2.89	2.99	38.03

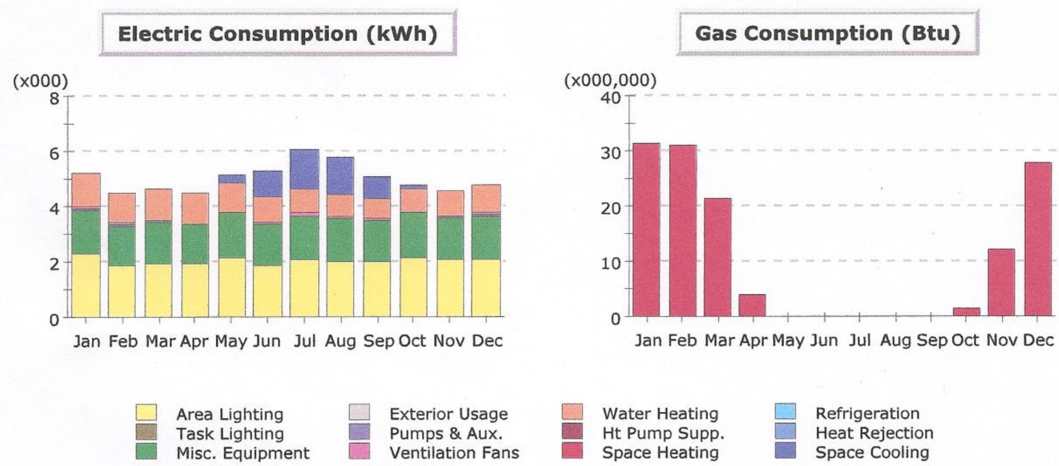
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	6.54	7.80	3.91	-	-	-	-	-	-	-	0.68	5.72	24.65
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	6.54	7.80	3.91	-	-	-	-	-	-	-	0.68	5.72	24.65

eQUEST 3.63.6510 | Monthly Energy Consumption by Enduse | Page 1

B.5 – 6000 Square Foot Baseline House

Project/Run: 6000 Sq Ft 1 - Baseline Design   Run Date/Time: 08/17/10 @ 20:33



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	0.29	0.92	1.39	1.32	0.80	0.12	-	-	4.83
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.18	1.07	1.14	1.09	1.07	0.88	0.86	0.78	0.75	0.86	0.91	1.03	11.62
Vent. Fans	0.09	0.09	0.06	0.01	0.03	0.09	0.13	0.13	0.08	0.02	0.03	0.08	0.82
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.63	1.42	1.51	1.47	1.60	1.47	1.57	1.54	1.50	1.60	1.53	1.57	18.39
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	2.26	1.89	1.93	1.89	2.17	1.89	2.10	2.01	1.97	2.18	2.06	2.10	24.45
Total	5.19	4.50	4.66	4.48	5.16	5.25	6.05	5.77	5.10	4.79	4.56	4.81	60.31

Gas Consumption (Btu x000,000)

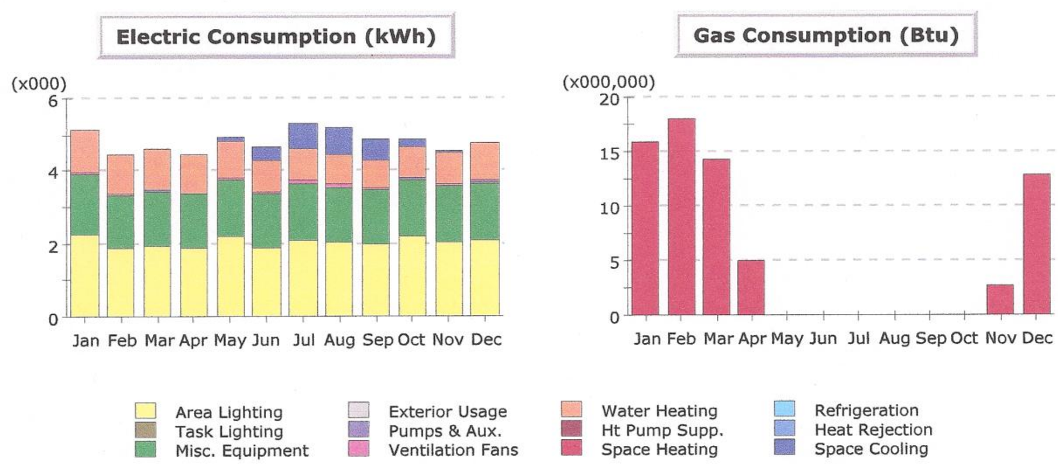
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	31.48	31.18	21.27	3.98	-	-	-	-	-	1.42	12.11	27.91	129.34
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	31.48	31.18	21.27	3.98	-	-	-	-	-	1.42	12.11	27.91	129.34

eQUEST 3.63.6510   Monthly Energy Consumption by Enduse   Page 1

B.6 – 6000 Square Foot SEE House

Project/Run: 6000 Sq Ft 2 - Baseline Design

Run Date/Time: 08/17/10 @ 20:50



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	0.06	0.36	0.69	0.76	0.55	0.22	0.01	-	2.66
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.16	1.06	1.13	1.08	1.06	0.87	0.85	0.77	0.75	0.85	0.90	1.02	11.50
Vent. Fans	0.04	0.05	0.04	0.01	0.01	0.05	0.09	0.11	0.08	0.03	0.01	0.03	0.55
Pumps & Aux.	0.04	0.03	0.03	0.01	0.00	0.00	-	-	0.00	0.02	0.03	0.03	0.20
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.62	1.41	1.51	1.47	1.59	1.47	1.57	1.54	1.50	1.60	1.53	1.57	18.36
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	2.26	1.89	1.93	1.89	2.17	1.89	2.10	2.01	1.97	2.18	2.06	2.10	24.45
Total	5.13	4.44	4.63	4.47	4.90	4.64	5.30	5.18	4.86	4.90	4.53	4.75	57.73

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	15.90	18.12	14.32	5.04	-	-	-	-	-	-	2.62	12.83	68.83
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	15.90	18.12	14.32	5.04	-	-	-	-	-	-	2.62	12.83	68.83

eQUEST 3.63.6510

Monthly Energy Consumption by Enduse

Page 1